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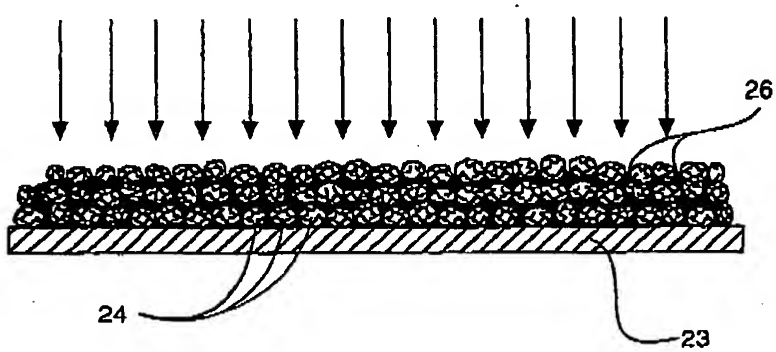

(57) Abstract

A cryopump array (21) is described. Each vane (23) of the array (21) is coated with a 3-dimensional adsorbing structure made up of an adhesive (26) which is transparent to passage of gases to be pumped by adsorption and a plurality of pieces of an appropriate adsorbing material (24) adhered on top of one another.

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CRYOPUMP

DISCLOSURE

Background of the Invention

The present invention relates to cryogenic vacuum pumping and, more particularly, to an apparatus and method for increasing the adsorbency of adsorbent pumping surfaces. It specifically relates to two-stage cryogenic pumping and an adsorbent panel for such a pump.

In high and ultra-high vacuum pumping, it is common to provide one or more adsorbent surfaces to "pump" certain gases via adsorption. Adsorption is a process by which a surface of a material retains via physical or chemical action another material which is brought into contact with it. (Adsorption is to be contrasted with absorption in which one material takes into the interior of the same another material.) It should be noted that it is adsorption, rather than absorption, when the surface of pores of a porous material retains another material.

Two-stage cryogenic pumps are used to pump via condensation those gases which condense at a low temperature, and to pump via both adsorbency and condensation those gases which pump at an even lower temperature. These pumps typically include one or more condensing surfaces at an initial or first stage for pumping gases which will condense at the higher temperature, such as

water vapor and carbon dioxide, and panels covered with an adsorbing material, such as activated charcoal or artificial zeolite at a second stage to pump those gases, such as oxygen, nitrogen, argon, helium, hydrogen and neon, which will be condensed or be adsorbed at a lower temperature. The first stage temperature typically is in the range of 50°-80°K, whereas the second stage is typically in the temperature range of 10°-22°K.

The adsorbent surfaces generally are a single layer of an adsorbent material adhered with a suitable adhesive, such as epoxy, to a panel or other substrate surface. The panel is maintained at the lower temperature and acts to cool the adsorbent material layer as well as condense those gases which do not condense in the first stage of the pump but will condense at its lower temperature.

The capacity of most adsorbent materials is quite limited. In general, a molecule or atom of a gas to be pumped must contact a surface of the adsorbent material before it will be pumped. Once a particular portion of the surface of an adsorbent material has pumped an adsorbent gas, such surface is no longer available to pump additional atoms or molecules of the gas. For this reason, the adsorbent material typically is provided as a multitude of small pieces having microscopic pores to increase the available surface area. These pieces are adhered as a single layer coating on a substrate with an adhesive. The adhesives used in the past for this purpose, e.g. epoxy, can cover and shield or, in other words, passivate a portion of the available surface area of the adsorbent material. One approach considered in the past to increase the capacity of cryogenic pumps is the concept simply of increasing the area within the pump which is coated with the single layer of adsorbent material. The problem with this is that it increases the refrigeration load on the pump. The surface area made available for adsorbency has been optimized in the past with this in mind.

While providing the adsorbent material over an optimum area as a plurality of pieces having microscopic pores is the standard way of dealing with the capacity problem, the pumps available at the time of this invention often require regeneration. In other words, as the surface of the adsorbent material gets "used", the capacity of the pump decreases to such an extent that the adsorbent process is discontinued by the pump operator and the pump is regenerated. That is, the operator terminates communication between the pump and the volume being pumped, and brings the pump to a higher temperature at which the adsorbent material surfaces will release the pumped gases. Such gases are then removed from the interior of the pump by standard techniques. The capacity of two-stage cryopumps available before the instant invention is in the order of 15-20 liters. That is, after pumping this volume of gas, the pumps must be regenerated.

Summary of the Invention

The present invention significantly increases adsorbent pumping capacity. This capacity is enhanced without the necessity of increasing the area within the pump which is coated with an adsorbent material. From the broad standpoint the invention includes the 3-dimensional adsorbent structure resulting from the combination of an adhesive which is transparent to passage of the gases to be pumped by adsorption and a plurality of pieces of the adsorbent material adhered to a substrate on top of one another by such adhesive. The use of the transparent adhesive enables the pieces of adsorbent material to pump in spite of the presence of such adhesive. That is, while in the past the traditional adhesives have resulted in passivation of the surface areas of the adsorbent material covered by the adhesive, the use of the transparent adhesive prevents the same from affecting the adsorbency of such surface areas. Besides increasing capacity, since the invention does not rely on increasing the lateral size of

the panels or other coated surfaces, it is easily retrofittable into most existing pumps.

As another major feature of the instant invention, the 3-dimensional adsorbing structure is provided with a sufficient thickness to form a natural temperature gradient in the direction of projected gas flow therethrough. That is, the coating on the panel is sufficiently thick to provide a temperature gradient from the panel to the exposed coating surface. This natural temperature gradient increases the capacity of the pump. That is, prior arrangements have suffered from molecular mobility loss of the gases to be adsorbed. This mobility loss is due to the temperature of the adsorbent material being sufficiently low to decrease the movement of the gases, causing a loss of diffusion of the same within the adsorbent. It will be recognized if the gases do not diffuse efficiently in the adsorbent, the capacity of the adsorbent material is underutilized. The temperature gradient provided by the 3-dimensional adsorbent structure causes the gases which are not adsorbed on the surface, to be adsorbed as the gases diffuse through the material. In this connection, those gas molecules which are not adsorbed on the surface because of their mobility will suffer a mobility loss as they travel in the 3-dimensional adsorbent structure and thereafter be adsorbed when meeting an adsorbent surface.

Other features and advantages of the invention either will become apparent or will be described in connection with the following, more detailed description of a preferred embodiment of the invention.

Brief Description of the Drawing

With reference to the accompanying drawing:

FIG. 1 is an isometric view of a two-stage cryogenic pump incorporating the instant invention;

FIG. 2 is an enlarged schematic view illustrating in section, the construction of the 3-dimensional adsorbent structure of the instant invention;

FIG. 3 is an enlarged sectional view similar to FIG. 2 of a typical prior art arrangement; and

FIG. 4 is an exploded view of the preferred embodiment illustrated in FIG. 1.

Detailed Description of the Preferred Embodiment(s)

The following relatively detailed description is provided to satisfy the patent statutes. However, it will be appreciated by those skilled in the art that various changes and modifications can be made without departing from the invention. The following description is exemplary, rather than exhaustive.

A two-stage cryogenic pump incorporating the invention is generally referred to with the reference numeral 11. Such pump includes an outer vacuum vessel 12 having a cylindrical opening at one end circumscribed by a mounting flange 13. Flange 13 includes typical bores 14 for securance of the same in accordance with standard practice via a gate valve or the like to a vacuum chamber to be pumped.

Vessel 12 houses a conventional refrigeration cylinder 16 axially within the same. Such cylinder supports and provides the desired low temperatures to the first and second stages of the pump. In this connection, in accordance with conventional practice the cylinder 16 relies on the condensation of helium to obtain the low temperatures. A compressor (not shown) supplies room temperature helium under pressure to the pump via connection 17, which helium is allowed to expand to provide cooling for the two stages of the pump.

The first or, in other words, initial stage of the pump is made up of a radiation shield 18 which supports an array 21 of coaxial annular fins. The array 21 provides the dual function of acting not only to provide an extended surface area for condensation at the initial stage, but also to protect the lower temperature condensation and adsorbent second stage from direct line-of-sight exposure to the gases to be pumped. With respect to the latter, such array is constructed to provide overlapping surface areas which block such line-of-sight but yet permit passage therethrough of those gases which do not condense on the same. It is thermally coupled via the radiation shield 18 to the central area of the cylinder 16 so as to be maintained at a temperature within the range of 50°-80°K. A washer 22 made of a good thermally conductive material, such as indium, is provided at the physical connection of the shield to the cylinder 16 to assure good thermal conduction between the two. The array 21 acts, in essence, as means positioned in the path of the flow of gases to be pumped for condensing particular ones of the gases.

The second stage of the pump includes an array, in this case eight, of condensing panels 23. The purpose of the condensing panels is not only to provide second stage condensing for those gases which will condense at a lower temperature, e.g., within the range of 10-22°K, but also to provide substrates for a coating of an adsorbent material. That is, the exterior underneath surface of each of the panels 23 is coated with a multitude of pieces of an adsorbent material.

In keeping with the invention, the surface coating includes a multitude of pieces 24 of an adsorbent material which are adhered thereto on top of one another by an adhesive 26 as is illustrated in FIG. 2. The adhesive is selected to be transparent to the passage of the gases to be pumped by adsorption. The coating includes a sufficient number of pieces of the adsorbent material so that pieces of

the same are completely encompassed by the transparent adhesive. The interior prices of the adsorbent material are completely encompassed by the adhesive and the interstices between adjacent pieces are filled with the transparent adhesive This is to be contrasted with prior art arrangements in which care is taken to assure that significant surface area of each of the pieces of adsorbent material remains exposed for adsorption.

A 3-dimensional adsorbent structure is provided by the invention. The construction can be thought of as a multi-layer adsorbent material construction, as opposed to the single layer construction which is conventional. A suitable mixture of both adsorbent pieces and a transparent adhesive is that sold by American Norrit Company, Inc., having a place of business at 1050 Crown Point Parkway, Suite 500, Atlanta, Georgia, with the designation Norithene Plates. The pieces of adsorbent material in this mixture are pieces of activated charcoal. It will be recognized by those skilled in the field that pieces of other materials, such as artificial zeolite, which are adsorbent to the gases to be pumped can be used. The adhesive is an organic polymer resin. It also will be recognized by those skilled in the art that other adhesives can be selected which meet the criteria of being transparent to the gases to be adsorbed.

As a major feature of the invention, the 3-dimensional structure of the invention confronts molecules of gases which may be adsorbed with a 3-dimensional adsorbing structure having a relatively significant thickness in the direction of gas flow. Those molecules having generally too much energy at the time of first contact with the adsorbent structure to be adsorbed, will pass through the surface into the interior of the adsorbent structure. Insofar as the theory of operation is concerned, it is believed these molecules will be slowed down by the structure and then captured by adsorption when they have an appropriate energy

state by contacting an adsorbent surface within the interior of the structure.

Most desirably, the adsorbent characteristics of the 3-dimensional structure are enhanced by maintaining a temperature gradient within the structure in the direction of gas flow therethrough, i.e., between the panel 23 and the exposed surface of the coating which is spaced away from such panel by the thickness of such coating. It has been found that most desirably the thickness of the adsorbent structure is such that the temperature of the exposed surface of the material most desirably is at least 1°K higher than that of the underlying panel. It is conjectured that this temperature differential aids in the adsorbent process by providing a reverse temperature differential for the adsorbent material throughout the structure, thereby cooperating with the mobility loss aspects of the 3-dimensional structure discussed above, to assure adsorbency.

The thickness of the coating will depend upon many factors, including the particular material that is used for adsorbency, the number of particles, the transparent adhesive, etc. The thickness is best defined from the standpoint of this invention in terms of the temperature. It is desirable that the adsorbent structure have sufficient thickness to provide the surface spaced away from the panel with a temperature as discussed above which is at least 1°K higher than the panel iteelf.

The construction of the invention is schematically illustrated in FIG. 2. In the past it has been the practice as shown in FIG. 3 to strive to maintain the adsorbent material in a single layer of pieces on the panel 23 and to reduce to the extent practical the adhesive which is used to maintain the pieces on such panel. The adhesives used in the past, typically an epoxy, have passivated the adsorbing

surfaces provided by the pieces of material, thereby reducing the adsorbency.

Each of the panels 23 is, in fact, provided by two separate panel halves 29 and 31 as is illustrated in FIG. 4. A top plate 32 for the panel array is also provided with a indium plate connector 33 providing good thermal conductivity between such plate and the remainder of the array. An L-bracket construction illustrated at 34 is used to maintain the entire construction within the interior of the pump securely adhered in thermal conductive relationship to the upper end 36 of the refrigeration cylinder 16. Thus, such cylinder provides the desired lower temperature for the second stage of the pump. It can be thought of as means for cooling the panels of the invention as well as for cooling the array 21 of the first stage. Moreover, it is responsible for providing the temperature gradient through the 3-dimensional adsorbent structure.

It is to be noted that except for the invention aspects, the pump is a Cryo-Torr® pump available from CTI Cryogenics, a Division of Helix Technology Corporation, having a place of business at 266 Second Avenue, Waltham, Massachusetts. Its use with the invention emphasizes the retrofittable nature of the invention.

As mentioned at the beginning of the detailed description, Applicant is not limited to the specific embodiment described above. Various changes and modifications can be made. The claims, their equivalents and their equivalent language define the scope of protection.

CLAIMS

What is claimed is:

1. A cryopump comprising the combination of:

(a) means positioned in the path of a flow of gases to be pumped for condensing particular ones of said gases;

(b) a panel having a surface to be exposed to gases to be adsorbed, which surface is coated with a multitude of pieces of an adsorbent material adhered thereto on top of one another by an adhesive which is transparent to the passage of said gases to be pumped by adsorption, thereby forming a 3-dimensional adsorbent structure; and

(c) means for cooling said condensing means and said panel.

2. The pump of claim 1 wherein said structure is sufficiently thick to provide a temperature gradient from said panel to that opposed surface of said structure spaced away by the thickness of said coating from said panel.

3. The pump of claim 2 wherein said surface is at a temperature which is at least 1°K higher than that of said panel.

4. The pump of claim 2 wherein said pieces of adsorbent material are selected from the group consisting of activated charcoal and artificial zeolite.

5. The pump of claim 1 wherein said means for cooling also is responsible for a temperature gradient in the direction of the flow of gases through said coating between an exposed surface thereof and said panel.

6. The pump of claim 1 wherein said adhesive is an organic polymer resin.

7. In apparatus for adsorbent pumping of gases in which a multitude of pieces of an adsorbent material is adhered to a substrate, the combination of an adhesive which is transparent to passage of the gases to be pumped by adsorption and a plurality of said pieces adhered on top of one another by said adhesive to form a 3-dimensional adsorbent structure.

8. The apparatus of claim 7 wherein interstices between said adjacent pieces are filled with said transparent adhesive.

9. The apparatus of claim 7 further including as part of said combination means for providing a temperature gradient in said 3-dimensional adsorbent structure in the direction of intended gas flow therethrough.

10. The apparatus of claim 9 wherein said means for providing a temperature gradient includes means for cooling said substrate to a desired low temperature and said 3-dimensional adsorbent structure extends away from said substrate in the direction of intended gas flow therethrough for a sufficient thickness to provide a surface spaced away from said substrate which is at least 1°K higher temperature than said substrate.

11. The apparatus of claim 7 wherein said adhesive is an organic polymer resin.

12. In a method of making a cryogenic pumping surface, the step of:

forming an adsorbent surface on a substrate by coating the latter with both an adhesive transparent to passage of gases to be pumped by adsorption and a multitude of pieces of an adsorbent material on top of one another, thereby providing a 3-dimensional adsorbent structure.

13. The method of claim 12 wherein said step of forming includes providing a sufficient number of pieces of said adsorbent material on said substrate to form a 3-dimensional adsorbent structure having pieces of said adsorbent material completely encompassed by said adhesive.

14. The method of claim 12 wherein said step of forming includes providing a sufficient number of pieces of said adsorbent material on said substrate to form a temperature gradient in said structure in the direction of flow of gases through said coating between an exposed surface thereof and said substrate.

15. An adsorbent panel for a cryopump having means positioned in the path of the flow of gases to be pumped for condensing particular ones of said gases, comprising:

(A) a substrate having a surface to be exposed to gases to be adsorbed;

(B) a coating of a multitude of pieces of a adsorbent material adhered on said surface on top of one another by an adhesive which is transparent to the passage of gases to be pumped by adsorption, forming a 3-dimensional adsorbent structure.

16. The panel of claim 15 wherein said coating on said substrate is sufficiently thick to provide a temperature gradient from said substrate to that surface of said coating spaced away by the thickness of said coating from said substrate.

17. The panel of claim 15 wherein interstices between said adjacent pieces are filled with said transparent adhesive.

18. The panel of claim 15 wherein said coating is sufficiently thick to maintain said surface at a temperature which is at least 1°K higher than that of said substrate.

19. The panel of claim 15 wherein said pieces of adsorbent material are selected from the group consisting of activated charcoal and artificial zeolite.

20. The panel of claim 15 wherein said adhesive is an organic polymer resin.

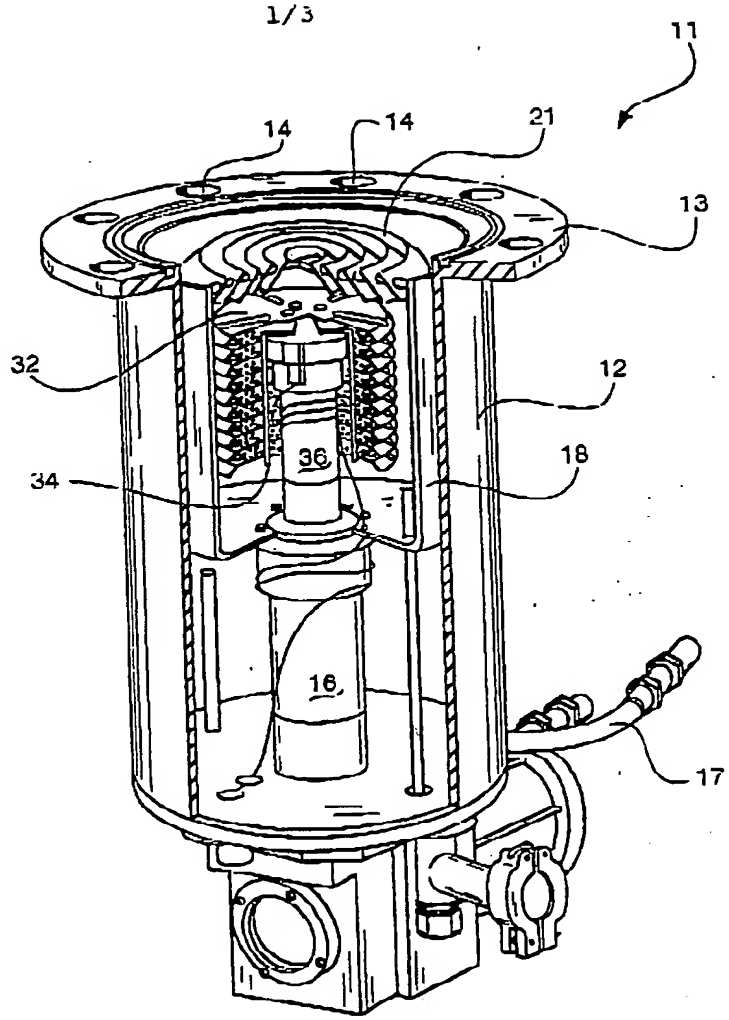

FIG.1

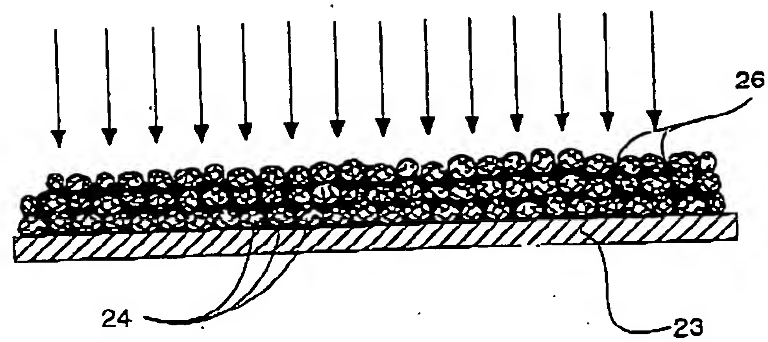

FIG.2

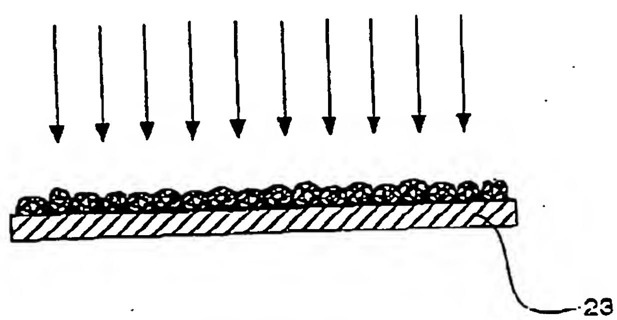

FIG.3
(PRIOR ART)

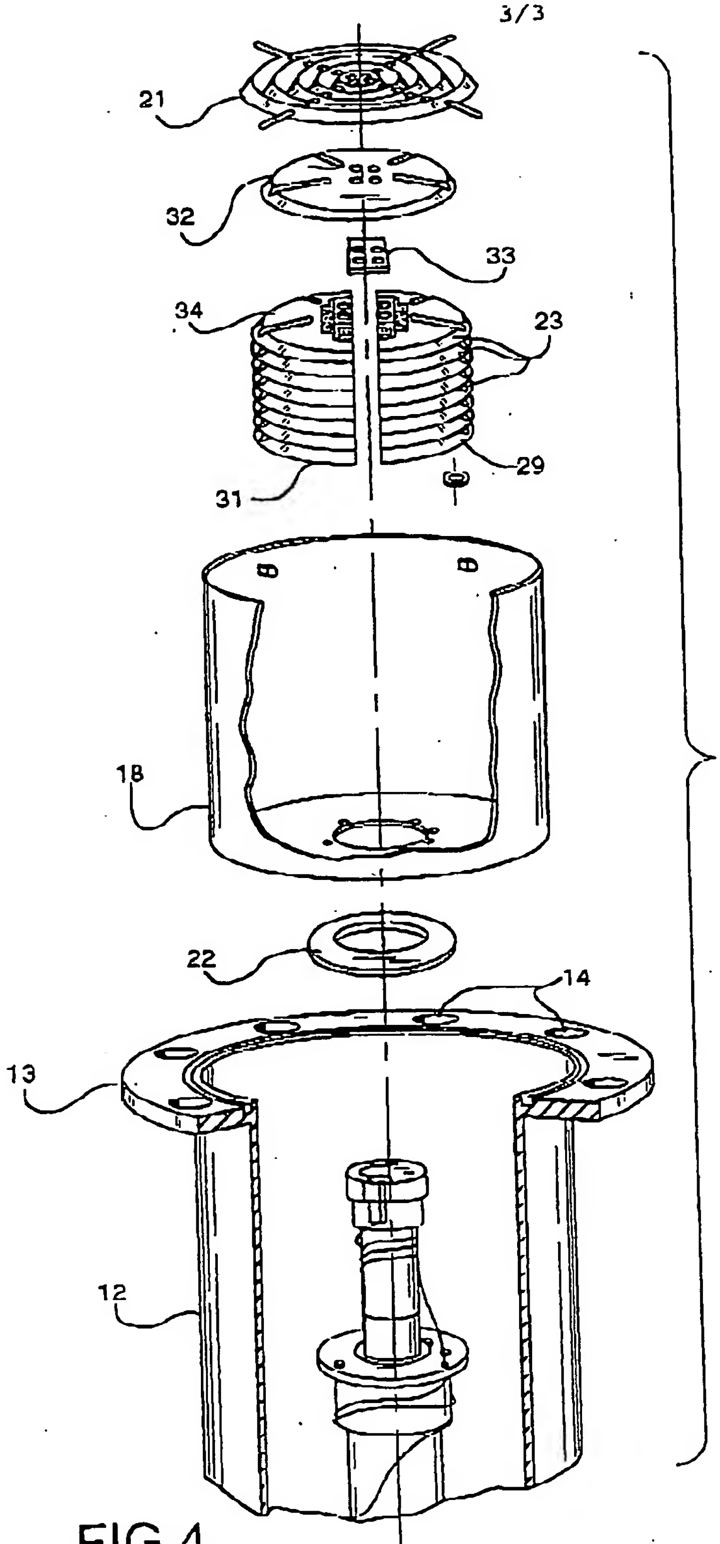

FIG.4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/06009

A. CLASSIFICATION OF SUBJECT MATTER

IPC(5) :B01D 8/00 B01J 20/00, 20/22, 20/26
US CL :62/55.5
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A, 3,309,844 (Hemstreet et al) 21 March 1967 See entire Document	1-20
A	US,A, 3,387,767 (Hecht) 11 June 1968 See entire document	1-20
Y	US,A, 4,325,220 (McFarlin) 20 April 1982 See entire document	1-20
A	US,A, 4,530,213 (Kadi) 23 July 1985 See entire document	1-20
A	US,A, 4,580,404 (Pez et al) 8 April 1986 See entire document	1-20
A	US,A, 5,000,007 (HAEFNER) 19 March 1991	1-20

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search

24 AUGUST 1993

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